A 12-YEAR OPHTHALMOLOGIC EXPERIENCE WITH THE SHAKEN BABY SYNDROME AT A REGIONAL CHILDREN'S HOSPITAL*

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ABSTRACT

Purpose: To examine the ophthalmologic experience with the shaken baby syndrome (SBS) at one medical center, including clinical findings, autopsy findings, and the visual outcome of survivors.

Methods: One hundred sixteen patients admitted from 1987 to 1998 for subdural hematomas of the brain secondary to abuse were included.

Results: Retinal hemorrhages were detected in 84% of the children, but this important finding had been missed often by nonophthalmologists. Poor visual response, poor pupillary response, and retinal hemorrhage correlated strongly with demise of the child. One child who died had pigmented retinal scars from previous abuse, a condition not previously observed histopathologically.

The clinical and autopsy findings varied somewhat, probably because of the differing conditions for examination. No correlation could be made between computerized tomography scans done during life and the subdural hemorrhage of the optic nerve found on autopsy.

Half of the surviving patients were known to have good vision. One fourth of the patients had poor vision, largely due to cerebral visual impairment from bilateral injury posterior to the optic chiasm. Severe neurologic impairment correlated highly with loss of vision.

Conclusion: This series provides information on the frequency of eye findings in SBS patients. No fundus finding is pathognomonic for SBS. When retinal hemorrhages are found in young children, the likelihood that abuse occurred is very high. The difficulty that nonophthalmologists have in detecting retinal hemorrhage may be an important limiting factor in

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finding these children so they may be protected from further abuse.

BACKGROUND

The shaken baby syndrome (SBS) is only one form of child abuse. It is particularly distressing because the very youngest and most helpless children suffer from it. It is characterized by subdural hematoma (SDH) of the brain, occult bone fractures particularly of the ribs, and retinal hemorrhages (RH). Very commonly, no history or only an inadequate history of injury can be obtained from the children's caretakers. Violent shaking alone can cause these injuries, but many infants also show signs of impact injury to the head from skull fractures to subtle soft-tissue bruises. The children are usually less than 3 years old.

Parts of the medical features of SBS have been known for almost 200 years. Parkinson[1] recognized that parents injuring their children could cause "dropsy of the brain." Tardieu in 1860 and Scattergood in 1875 published reports of autopsies of maltreated children with subdural hematoma.[2,3]

In 1928, Aikman[4] reported a child who had subarachnoid and probably subdural hemorrhage, increased intracranial pressure, and retinal hemorrhages, whose father had been convicted of abusing a sibling. The mechanism of injury was not known to him.

The constellation of trauma, SDH, and RH in an infant under 1 year of age, with a substantial risk of loss of vision, became well recognized.[5,6] That the lack of a history of trauma or a history of a fall, now considered characteristic features of a history given for a SBS patient, could point to abuse as a cause was not known.[5-7] Sherwood[8] did comment on "dubious home conditions" for some of his patients.

The entire recurring clinical picture of multiple traumas was first published by Caffey[9] in 1946, but abuse and the mechanism of the trauma were not known to him then. Shaking as the mechanism was first described in print by Guthkelch[10] in 1971 but was popularized by Caffey in 1972.[11]

It was not until Gilkes' short letter that the high frequency of RH in SBS was recognized.[12] RH continues to be seen most often in head trauma due to abuse rather than from other causes.[13,14]

There has been considerable discussion regarding the exact types of trauma in these patients. While shaking alone can cause the entire clinical picture,[15-17] many patients have evidence of impact injury to the head also, if carefully examined.[15,18,19] The impact is probably often against softer objects such as a mattress because the bruising can be very subtle, even requiring shaving of the head to be visible. Single severe impacts can also cause SDH and RH.[20] Some investigators prefer the term "shaken impact syndrome" to SBS.[21,22] The exact types of injury continue to be hidden by perpetrators. There is a spectrum of apparent injuries from only shaking to shaking plus impact.

Research on the biomechanics of brain injury has not included studies of RH.[23,24] The roles of increased intracranial pressure and venous obstruction versus vitreous separation from acceleration and deceleration in the formation of intraocular hemorrhage and retinal folds continue to be debated in the literature.[17,25-28] Sudden increases in chest or head pressure may be part of the cause also.[29]

SBS is a serious public health problem, injuring an estimated 1,800 children in the United States each year.[30] One third of the recognized patients die acutely, and 80% of survivors have significant neurologic handicaps.[30] Hypoxia and ischemia due to the apnea that frequently occurs may be the major causes of the brain injury rather than impact or shearing.[31] It has been suspected that up to one third of mentally retarded children have had abuse that contributed to their impairment.[10] Many children are abused repeatedly. If abuse could be recognized early, subsequent injuries could be prevented.[32]

Because there are rarely obvious external signs of head injury to prompt the ordering of computerized tomographic (CT) scans, SBS can go undetected. An eye examination that reveals retinal hemorrhages is extremely helpful in making this diagnosis because of the high correlation of RH with SDH.[5,6,13] Yet there continues to be an aversion among the pediatric community to subjecting patients to dilated fundus examinations. There also continues, among the ophthalmology community, a lack of realization of how very likely the retinal hemorrhages in a young infant are due to abuse rather than to the other causes on the very long list of differential diagnostic considerations for retinal hemorrhages.[13,27,30,33]

More recent clinical ophthalmologic series of SBS patients have had relatively small numbers of patients and have tended to stress particular features, such as retinoschisis and dome-shaped hemorrhages,[25,34] circular retinal folds,[17,25,35] and vitreous hemorrhage.[36,37] The largest ophthalmologic series have been of consecutive autopsy cases.[33,38] No series has examined a medical center's comprehensive experience including the clinical findings of the entire population, the visual outcome of the survivors, and the histopathologic findings of the deceased patients.

METHODS

STUDY SETTING

This 220-bed children's hospital serves a large geographic area with a population of about 1.8 million people. It is a center for trauma care with a

Flight for Life medical transportation service and a 24-bed intensive care unit. The Child Advocacy Center of the hospital has a full-time pediatrician and social worker. It receives 2,000 referrals each year to evaluate a child for possible abuse. The Department of Ophthalmology has a residency training program with 12 full-time ophthalmologists, including 2 pediatric ophthalmologists and an eye pathologist. Full time coverage for ophthalmology care is provided at this hospital, which is part of a medical school complex. The Eye Pathology Laboratory processes an average of 75 pairs of eyes for the medical examiner each year.

PATIENT SELECTION

Patients were ascertained from the consultation records of the Ophthalmology Department and from the records of the Child Advocacy Department and the Eye Pathology Laboratory. All children under 3 years of age who suffered subdural hematomas from abuse were included. Many patients had evidence of impact injuries to the head and body and fractures of the ribs and long bones. All had been admitted to the hospital, except one who was pronounced dead in the emergency department. The study was retrospective for those admitted from 1987 to 1996 and prospective from 1996 to 1998.

Clinical ophthalmology consultations were done only on request from the admitting pediatrician, frequently on the suggestion of the Child Advocacy Department. Histopathologic studies were done only on request by the medical examiner in the child's area of jurisdiction. However, the Child Advocacy Department screened all new admission data on a daily basis, looking for potentially abused children, and entered into the child's care. The Radiology Department frequently alerted the Child Advocacy Department when subdural hemorrhage, skull fractures, or multiple rib fractures were detected.

Patients were excluded if the Child Advocacy Department concluded that the injury had not been from abuse. One patient had pertussis as the cause of the subdural hematomas, and another had a witnessed fall of several feet where an adult also fell on top of him, causing a frontal bone fracture, SDH, and RH.

Several patients with abusive head trauma also were excluded because they had small subdural hemorrhages only adjacent to their skull fracture, indicating a single impact event rather than a shaking injury. Among the patients ascertained through the Eye Pathology Laboratory records because they had retinal hemorrhages, 4 were excluded because an automobile accident was the cause of their injuries, and 1 was excluded because she had bacterial meningitis and no other suspicion of abuse. Two abused children with retinal hemorrhages were excluded because they were over 3 years of age.

EXAMINATIONS

Initial Evaluations

The extent of the eye examination was dictated by the fragility of the patients. The examinations included a clinical ascertainment of visual acuity, pupillary response, motility and alignment, anterior segment examination, and fundus examination. Visual field testing according to distractibility was done if possible. Fundus photography was obtained largely for forensic documentation, as the pediatricians stressed the need for brief, nonstressful examinations.

Many patients were treated acutely for seizures and paralyzed for endotracheal intubation. Because the medications used could influence visual reaction, and pupillary size and reaction,[39] the assessment of these clinical findings was derived from the patient record made prior to the use of such medications. Emergency personnel routinely judged visual response and pupil size and reactivity as part of their patient evaluation.

Subsequent Examinations

Inpatients were seen at approximately weekly intervals. Outpatient follow-up of surviving patients was attempted but often thwarted by the patients' social situation of being in foster care, living in a different county, or moving out of state to live with relatives. An age-appropriate eye examination was done to assess any visual limitations the child might have for rehabilitation and schooling and any ocular sequelae of the injury.

Data obtained from the patients' records were analyzed, and statistical analysis was applied if the data were sufficient.[40]

Histopathologic Examinations

The globes were removed by the personnel of the Medical Examiner's Office. Some early specimens had vitreous aspiration for chemistry testing. The globes were fixed in a formalin solution and sectioned horizontally to include the pupil and optic nerve. They were examined grossly and microscopically, including staining for hemosiderin.

RESULTS

PATIENT CHARACTERISTICS

One hundred sixteen patients were included in the study. Seventy patients were male (60%) and 46 were female. An age distribution is given in Fig 1. Sixty percent were 6 months of age or younger. Race distribution is given in Table I. The race distribution for this hospital's patients is 84% white, 12% African American, and 6% other.

Twenty-four percent of the patients were born prematurely (<37 weeks gestation), and 3 patients were known to have developmental delays

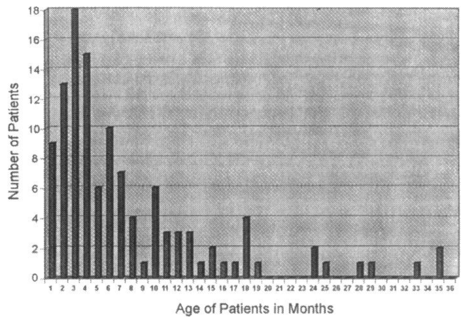

FIGURE 1

Age distribution of patients.

TABLE I: RACE DISTRIBUTION	
RACE	**NO. OF PATIENTS (%)**
White	56 (48)
African American	45 (39)
Hispanic	12 (10)
Asian	3 (3)

before their admission for abuse. Three patients had siblings who had died from sudden infant death syndrome or indeterminate causes. One child's sibling had been found to be abused and was returned to the family after court investigation and counseling. Two other families had been investigated and counseled by the county social services department for spousal abuse.

The number of patients admitted in each year of the study is given in Table II. The large increase in patients after 1990 reflects increased clinical activity in the Child Advocacy Department and the arrival of a new medical examiner, with a particular interest in the autopsy findings of victims' eyes.

The month of admission is summarized in Fig 2. Historically, the Child Advocacy Department sees more abused children in the months of February, March, and April in this cold climate.

Thirty-one patients had a previous medical encounter within 6 weeks of their admission for brain injury. Ten were admitted for seizures or fever, common presenting histories for abuse. One patient was admitted for a skull fracture with a plausible history. One child had an ophthalmology consultation as part of a Child Advocacy evaluation, which was normal. Twenty-one children had been seen as outpatients for reasons ranging

TABLE II: YEAR OF ADMISSION

YEAR	NO. OF PATIENTS
1987	1
1988	1
1989	2
1990	4
1991	13
1992	10
1993	15
1994	11
1995	20
1996	14
1997	13
1998	12

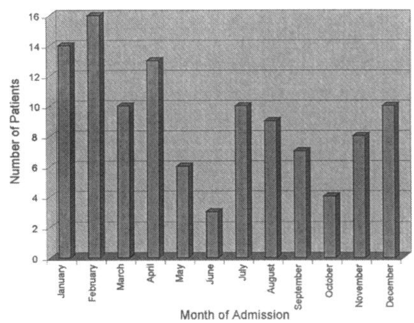

FIGURE 2
Number of patients admitted according to month of year.

from immunizations, to fever and vomiting, to a torn frenulum, which was not recognized as a classic sign of abuse in another hospital. One child had a Child Advocacy evaluation because of bruising, but no eye examination. Four of these 21 children died, and 4 lost their vision to subsequent abuse while 1 of the children who had been admitted lost vision.

Five patients presented relatively late because of increasing head size noted on a medical encounter. The remainder had acute neurologic deterioration. In many of these very young children, the admitting diagnosis was "rule out sepsis."

EVALUATIONS

INITIAL EYE EVALUATIONS

Initial Visual Response. Patients' initial vision was classified as unresponsive, responsive to light, or visually alert and attentive (Table III). Fourteen patients did not have visual responsiveness specifically recorded before they were sedated. In only 1 patient could visual acuity be quantitated because he was stable enough for formal testing. Only one third of the patients were visually alert at their first medical encounter.

TABLE III: INITIAL VISUAL REACTION

REACTION	DIED	LIVED	TOTAL
Unresponsive	29	21	50
Responsive to light	0	12	12
Visually alert and attentive	0	40	40
No information	5	9	14

Initial Pupillary Response. The first recorded assessments of pupillary response were analyzed. The majority of patients had reactive pupils (Table IV).

Motility and Alignment. Bilateral sixth nerve pareses were found in 1 patient. In many comatose, pharmacologically paralyzed, or irritable patients, motility and alignment could not be assessed accurately on their first examination. As obtundation cleared, 1 other patient was found to have a unilateral complete third nerve palsy and 4 patients were found to have horizontal gaze pareses.

Anterior Segment. No anterior segment abnormalities were found clinically. One patient was found to have bilateral filtering angle recessions at autopsy (see below).

Fundus Examination. Eighty-nine patients (77%) had an available record of a dilated funduscopic examination by an ophthalmology attending and/or resident (Table V). For an additional 15 patients, where the

TABLE IV: INITIAL PUPILLARY RESPONSE

REACTIVITY	DIED	LIVED	TOTAL
Reactive	1	63	64
Sluggish	3	2	5
Small, unreactive	2	3	5
Fixed and dilated	15	2	17
Asymmetric size or reactivity	2	9	11
No information	12	2	14

TABLE V: RETINAL HEMORRHAGES

FOUND BY	BILATERAL	UNILATERAL	NO HEMORRHAGE	TOTAL
Ophthalmologist	62	10	17	89
Pathologist only	14	1		15
Child Advocacy physicians only	4			4
Inadequate examination				8
Total	80	11	17	116
Percent of 108 patients examined	74%	10%	16%	

clinical record was no longer available or an ophthalmology consultation had not been requested, there were Eye Pathology Laboratory photographs and reports, yielding a 90% ophthalmologic assessment. For the remaining patients, 4 were found to have massive bilateral retinal hemorrhages by Child Advocacy physicians. Five other patients were reported as normal with undilated pupils by non-Child Advocacy pediatricians, and for 3 patients, no mention of fundoscopy could be found anywhere in the chart.

Retinal hemorrhages were the most common ocular finding. They were detected in 78% of the entire group or 84% of the 108 who had adequate fundus examinations (Table V). A large majority of patients had bilateral retinal hemorrhages. Other characteristics of the hemorrhages, noted by ophthalmologists or pathologists, supplemented by photographic review, are given in Table VI. Eleven patients were examined both clinically and at autopsy and are included in both columns of Table VI.

The majority of bilaterally affected patients had many intraretinal and preretinal hemorrhages. The hemorrhages were noted to extend beyond the vascular arcades in about one third of cases, but the extent of hemorrhages was not recorded for one fourth of the patients. While the number of patients was only 11, it appeared that unilaterally affected patients had fewer and less extensive hemorrhages. The occurrence of retinal hemorrhages was more common in the older patients, but the number of patients in each older age group was progressively smaller (Table VII).

Despite many patients being known to have cerebral edema, optic disc edema was rarely observed in living patients (Table VIII). However it was found in 5 of the 15 autopsy examinations where a clinical examination record was not available. Perimacular circular folds were found in only 6 patients (6%). Retinal edema and exudates were also rare. One choroidal

TABLE VI: CHARACTERISTICS OF RETINAL HEMORRHAGE*

FINDING	CLINICAL EXAMINATIONS (89 PATIENTS)	AUTOPSY EXAMINATIONS (27 PAIRS OF EYES)
Bilateral	62	24
Unilateral	10	1
None	17	2
Asymmetric bilateral involvement	6	16
Posterior pole most heavily affected	23	2
Peripheral retina near ora serrata affected	None noted	20
Domelike hemorrhages under ILM, any size	7	4
White centered hemorrhages	18	15
Preretinal hemorrhage	36	11
Subretinal hemorrhage	9	10
Vitreous hemorrhage	14	15

ILM, internal limiting membrane; RH, retinal hemorrhage.
*Eleven patients were examined both by ophthalmologists and the pathologist.

TABLE VII: RETINAL HEMORRHAGES AND AGE

AGE (MO)	NO. OF PATIENTS	TOTAL WITH RH	BILATERAL	UNILATERAL	NONE
0-3	38	27 (71%)	24 (63%)	3 (8%)	11 (29%)
4-6	29	25 (86%)	24 (83%)	1 (3%)	4 (14%)
7-12	21	19 (90%)	14 (67%)	5 (24%)	2 (9%)
13-24	14	14 (100%)	14 (100%)		
25-36	6	6 (100%)	4 (67%)	2 (33%)	

rupture was found clinically without external or anterior segment signs of direct trauma. No patients had funduscopic changes of retinopathy of prematurity.

Since the discovery of retinal hemorrhages is a key physical finding pointing toward a high probability of abuse, and nonophthalmologists are the first physicians to examine children with head injuries, charts were examined for all reports of fundus findings. For 80 patients, both an ophthalmology consultation report and the inpatient record were available (Table IX).

For 32 patients, fundus visualization was not adequately achieved. Five patients with retinal hemorrhages were felt to be normal. In only 1

TABLE VIII: OTHER FUNDUS FINDINGS

FINDING	CLINICAL EXAMINATIONS (89)*	AUTOPSY EXAMINATIONS (15)†
Exudates	4	0
Retinal edema	5	2
Retinal folds	4	2
Choroidal rupture	1	0
Optic nerve edema	4	5

* Clinical examinations were by ophthalmologists only.
† Pathology examinations include only those patients for whom a clinical examination was not available.

TABLE IX: RETINAL HEMORRHAGES: NONOPHTHALMOLOGISTS VERSUS OPHTHALMOLOGISTS

	NONOPHTHALMOLOGISTS' FINDINGS						
OPHTHALMOLOGIST FINDINGS	AGREE	NO RH OU	RH OU	RH 1 EYE	COULD NOT SEE	⊕RED REFLEX	NO COMMENT
Bilateral RH	28	5		5	8	5	5
Unilateral RH	1		5		2	1	
No RH	3			1	7	3	1
	32 total	5 false negative	5 partly correct	5 partly correct 1 false positive	17 unable to see	9 wrong technique	6 incomplete exam

OU, both eyes RH, retinal hemorrhage.

eye of 1 patient was a "suspicion of retinal hemorrhage" erroneously noted; the ophthalmology consultation was performed on the following day. The patient had presented late with only an enlarged head. In 37 patients where RH were not seen by nonophthalmologists, 70% had bilateral or unilateral RH. Three patients' pupils were dilated by pediatricians in the emergency department or on the inpatient floor, leading to the important discovery of retinal hemorrhages and ordering of appropriate radiologic studies that confirmed the diagnosis of SBS.

Neurologic and Other Evaluations

Fifty-seven patients had seizures on presentation or during their admission. The neurologic aspects of 8 of the patients were previously reported in a study on head-injured patients.[41] The perpetrators, explanation of injury, and skeletal injuries of 71 of the children were reported previously.[42] A report on the Glasgow Coma Scores, acute neurologic findings, CT scans, other injuries, neurologic outcome, social situations, and legal proceedings for patients admitted from 1990 to 1994 will be reported elsewhere.

Impact injuries were noted in many patients. Eighteen had skull fractures, while a total of 25 had visible bruising of the head and a total of 17 had bruising or edema of the eyelids or periorbital region. Fifty-five patients had no record of any impact injury to the head or eyes, but the patient evaluations were not done in a standardized, prospective manner specifically studying impact injuries. Sixty percent of these 55 patients had bilateral RH, and 7% had unilateral hemorrhage.

HOSPITAL COURSE

Follow-up of patients occurred at irregular intervals dictated by their medical states. Length of stay for survivors varied from 6 days to 8 months. Visual attentiveness improved markedly in 10 patients who had poor vision prior to sedation over periods of time from 12 hours to 4 weeks. Nine of these patients improved to normal for their age. One patient improved from unresponsive to looking toward loud noises over 1 month and was not seen after that. In 8 other patients, it could not be determined if the initial unresponsiveness was due to being in a sedated or postictal state; they improved in less than 2 weeks.

Small splinter hemorrhages were observed to disappear in 3 to 7 days in 2 patients clinically, and small dot hemorrhages had disappeared in 1 eye of another patient in the 11 days before death. Large preretinal hemorrhages slowly shrank in size over several weeks in several patients. Resolution of hemorrhages was not specifically studied.

OUTCOME

Death

Thirty-four patients died of their head injuries (29%). One died after discharge from the hospital, from a chronic vegetative state. One other patient died several years later of leukemia. Lack of visual response (Table III) proved to be highly correlated with demise (Fisher's exact test, $P<.0001$). The odds of dying for a patient with large or small unreactive pupils was 127 times higher than if the pupils reacted well or sluggishly (relative risk, $P<.0001$). Asymmetric pupil size or reactivity did not increase the odds of dying (Table IV). Also, a patient who did not have seizures had 5.88 greater odds of dying than one with seizures (relative risk, $P=.0003$). Retinal hemorrhages occurred more frequently in patients

TABLE X: RETINAL HEMORRHAGES VERSUS MORTALITY*

	DIED	LIVED
Total patients	34	82
Bilateral RH	91%	60%
Unilateral RH	6%	11%
No RH	3%	19%
No information	0%	8%

RH, retinal hemorrhage.
*RH was detected by ophthalmologists or pathologists. The earliest examination were used.

who died of their head injuries (chi-square test, $P<.05$) (Table X). Three of the 6 patients who had circular retinal folds died.

Histopathologic Observations and Clinical Correlations

Case Report. A 29-month-old girl was brought to the emergency department in a coma. She had been in the care of her grandparent's who initially denied any injury. She had extensive bruising on her head, face, limbs, and chest, including loop-shaped marks, which are pathognomonic of abuse. She also had marks of restraints on both wrists and many old burn marks. Retinal hemorrhages were found in both eyes. She died the day after admission. After confrontation, her grandmother stated that the patient had been resisting efforts to toilet train her and had been swearing at her, causing the grandmother, who had a headache, to lose her temper and shake her. Both grandparents described her as acting dazed and falling down the stairs after that. There was radiologic and histopathologic evidence of many previous injuries of varying ages. A laceration of the corpus collosum was found on examination of her brain. Both grandparents were convicted of homicide.

At autopsy, the right eye had a mild filtering angle recession, while the left eye had a marked angle recession. Both eyes revealed scarring and atrophy of the temporal retina from just anterior to the equator to the ora serrata. The lesions were multiple and were sharply circumscribed (Fig 3). The gross appearance of the scarring was similar to the clinical peripheral scarring reported previously.[43-45] Microscopically, these scars demonstrated focal areas of retinal pigment epithelium (RPE) atrophy with atrophy of the outer retina (Fig 4). Focal hemosiderin staining was noted elsewhere in the retina and in the optic nerve of the right eye only.

Other Observations and Correlations. One of the patients observed to have circular retinal folds died 3 days later, and the eyes were examined

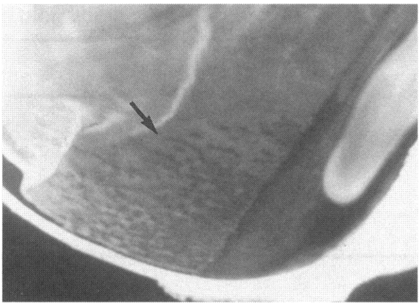

FIGURE 3
Gross appearance of retinal scars of reported case. Arrow points to affected area.

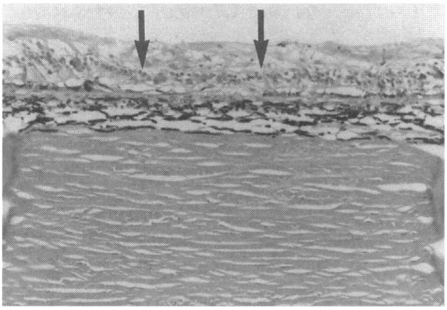

FIGURE 4
Histopathologic appearance of retinal scarring. Between arrows is an area of retinal pigment epithelium and outer retina atrophy.

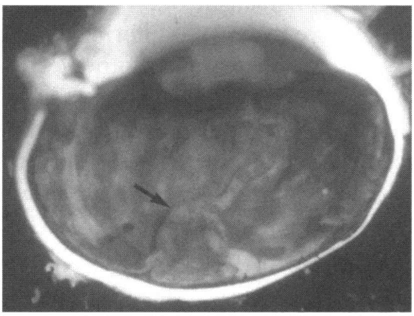

FIGURE 5
Gross appearance of circular perimacular retinal fold (arrow).

(Fig 5). The internal limiting membrane (ILM) was detached central to the fold.

In 2 patients not examined clinically, unilateral circular perimacular folds were present. In another patient not examined clinically, retinal hemorrhages of varying colors were noted in each eye. She presented acutely ill on the first day her mother's boyfriend stayed alone with her, and she died on the following day. Previous medical encounters or episodes of illness suggestive of abuse were not admitted.

Another patient had focal iron staining scattered throughout the retinas. No previous episodes of injury could be detected by history or found in our records. Two patients had intrascleral hemorrhage.

In 2 patients who clinically had retinal hemorrhages, none was identified pathologically. One patient, who died acutely, had tiny splinter hemorrhages near both optic nerves, seen by the staff and resident ophthalmologists the day she died. As mentioned previously, the other patient had a few dot hemorrhages in 1 eye, which were not visible at autopsy 11 days later. While iron staining is routinely done, attempts to section the eyes through the areas where the small hemorrhages had been observed clinically were not made.

In 24 of the 26 autopsy cases, subdural hemorrhage and/or subarachnoid hemorrhage were found around both optic nerves, including the 3 eyes that had no RH. A child with Down syndrome and extensive bilateral RH and another child with only a few RH in 1 eye and microscopic sub-ILM hemorrhage in the other eye had no optic nerve sheath hemorrhage. The CT scans of 22 of the patients were available for clinicopathologic correlation. Even retrospectively, knowing the length of the optic nerve specimen, no abnormalities could be identified on the CT scans. Also, no posterior orbital hemorrhage could be detected. The CT scans in these moribund patients tended to have thick axial slices in order to be completed in less time, and sometimes did not even go down to the level of the optic nerve.

Survivors

Visual Outcome. Outpatient follow-up to assess visual outcome could be obtained for 55 patients, or 67% of those who survived. Follow-up periods ranged from 2 months to 5 years, but often patients were too young for visual acuity charts and too active or inattentive for Teller acuity testing. Patients were considered to have a good visual outcome if they fixated upon and followed small objects and were attentive to objects in their environment more than 10 feet away, or if they had 20/40 acuity or better on an acuity chart. Poor visual outcome was defined as unsteady fixation, light perception or no light perception, less than 20/200 acuity on the

TABLE XI: FINAL VISION VERSUS INITIAL VISION

	FINAL VISION				
INITIAL VISION	GOOD	POOR	POOR IN ONE EYE	GOOD INITIALLY, NO FOLLOW-UP	NO INFO.
Fixates and follows	24			16	
Light perception	7	2	1		2
Unreactive	5	12			4
No information	4	2	2		1
Total	40 (49%)	16 (19%)	3 (4%)	16 (19%)	7 (9%)

Teller acuity cards at age 2 years or older, and homonymous hemianopsia. The outcomes are given in Table XI. Almost one half of the patients were known to see well at their last visit, while one fourth had some visual impairment. Initial and final vision were significantly correlated (chi-square, $P<.0001$). It is likely that those patients who had normal visually guided behavior at discharge did not have acuity of less than 20/200 later, although milder deficits in acuity or defects in visual fields could become apparent later.

Cerebral visual impairment (CVI) due to bilateral brain injury posterior to the optic chiasm was the most common cause of bilateral visual impairment, accounting for at least 11 (85%) of the 13 bilaterally affected patients (Table XII). In 5 patients with optic atrophy, the good reactivity of the pupils despite very poor vision was interpreted as indicating the patient had CVI also. One patient was found to be highly myopic (patient 6, Table XII). The original fundus abnormalities are unknown. If he did have dense vitreous hemorrhages causing visual deprivation, there were no suggestive fundus findings later. Vision did not improve as he wore spectacles. Three patients were found to have homonymous hemianopsia. Case 14 had unilateral visual acuity loss in addition to the visual field defect.

The unilaterally affected patients are listed in Table XIII. The first patient had retinal and optic atrophy in that eye (Table XIII). For the second patient, the rehabilitation clinic notes referred to patching (supervised elsewhere) for a constant and persistent unilateral strabismus. The retinal hemorrhages were only in that eye, so it may have retinal damage leading to a sensory deviation. The final patient had no apparent structural or functional defects and appeared to have strabismic amblyopia only.

The presence or bilaterality of retinal hemorrhages did not show a correlation with visual outcome. The occurrence of seizures showed a corre-

TABLE XII: PATIENTS WITH BILATERAL VISION LOSS OR VISUAL FIELD DEFECT

PATIENT NO.	AGE AT ADMISSION (MO)	ACUTE FINDINGS	LENGTH OF FOLLOW-UP	FINAL VISION	PUPILLARY RESPONSE	FUNDI	CAUSE
1	2	No hemorrhage	2 yr	NLP	Reactive	Pale optic nerves, normal retinas	CVI, optic atrophy
2	1	RH OD	8mo	LP	Reactive	Normal	CVI
3	18	Bilat RH	2 yr	LP	Reactive	Normal	CVI
4	10	Bilat RH	5 yr	LP	Reactive	Normal	CVI
5	7	Bilat RH (non-ophthalmologist only)	2 yr	Unsteady fixation, <20/200	Reactive	Pale optic nerves, normal retinas	CVI, optic atrophy
6	1	Not examined	4 yr	<20/2000, Teller acuity with -13.50, -14.50	Reactive	Normal	CVI
7	5	Bilat RH, circular perimacular retinal folds	4 yr	LP	Reactive	Optic atrophy OU, mild hyper-pigmentation both maculas	Optic atrophy due to retinal disease, possible CVI
8	4	Bilat RH	2 yr	LP	Reactive	Normal fundi	CVI
9	3	Bilat RH	2 mo	LP	Reactive	Not examined	Probable CVI
10	13	Bilat RH (non-ophthalmologist only)	2 yr	NLP	Reactive	Mild optic atrophy, normal retinas	CVI, optic atrophy
11	36	RH OD	2.5 yr	NLP	Reactive	Normal	CVI
12	11	Bilat RH	2.5 yr	LP	Reactive	Mild optic	CVI, optic atrophy

TABLE XII (CONTINUED): PATIENTS WITH BILATERAL VISION LOSS OR VISUAL FIELD DEFECT

PATIENT NO.	AGE AT ADMISSION (MO)	ACUTE FINDINGS	LENGTH OF FOLLOW-UP	FINAL VISION	PUPILLARY RESPONSE	FUNDI	CAUSE
						atrophy, normal retinas	
13	4	No RH	15 mo	Follows light only, no OKN	Reactive	Normal	CVI
14	4	Bilat RH (non-ophthalmologist only)	5 yr	LP OS Good fixation OD	Left APD	Persistent vitreous hemorrhage OS for 5 mo, right HH	Retinal or optic nerve injury, left hemisphere injury
15	27	Bilat RH	2 mo	Good fixation, right HH	Reactive	Normal	Left hemisphere injury
16	2	No RH	19 mo	Good fixation, right HH	Reactive	Normal	Left hemisphere injury

APD, afferent pupillary defect; Bilat, bilateral; CVI, cerebral visual impairment; F/U, follow-up examination; HH, homonymous hemianopsia; LP, light perception; mo, months; NLP, no light perception; OD, right eye; OKN, optokinetic nystagmus; OS, left eye; RH, retinal hemorrhage.

TABLE XIII: UNILATERAL VISION LOSS

PATIENT NO.	AGE AT ADMISSION (MO)	ACUTE FINDINGS	LENGTH OF FOLLOW-UP	FINAL VISION	PUPILLARY RESPONSE	FUNDI	CAUSE
1	2	Bilat RH	11 mo	LP OS	Left APD	Optic atrophy, retinal atrophy	Retinal injury
2	8	RH OD only	Elsewhere	Patched OS for strabismus OD.	No information	No information	Unknown retinal problem or amblyopia
3	4	Bilat RH	15 mo	Fixates less well OS, constant unilateral esotropia	Normal	Normal	Strabismic amblyopia, no F/U

APD, afferent pupillary defect; Bilat, bilateral; F/U, follow up examination; LP, light perception; mo, months; OD, right eye; OS, left eye; RH, retinal hemorrhage.

lation with poor visual outcome (Fisher's exact test, P=.03).

Neurologic Outcome. Neurologic outcome was not the focus of this study but was interesting in view of the cerebral visual impairment observed. A long-term comprehensive neurologic study is under way and will be reported elsewhere. From the hospital outpatient charts, severe impairment was defined as hemiparesis, ataxia, severe developmental delay per a neurologist's or psychologist's report or a requirement for special education services. Mild impairment included attention deficit disorder or a mild speech delay for age. Normal development for age at the last visit was considered normal. Table XIV summarizes the findings. Follow-up ranged from only a few months to 5 years and was known for 47% of survivors. Twenty-four percent of all survivors were known to be severely impaired. Three patients had been known to be developmentally delayed before their injuries.

TABLE XIV: NEUROLOGIC OUTCOME AT LAST FOLLOW-UP

	NEUROLOGIC OUTCOME			
VISUAL OUTCOME	GOOD	MILDLY IMPAIRED	SEVERELY IMPAIRED	NO INFORMATION
Good	10	5	6	19
Poor		1	9	5
Poor in one eye			1	
No follow-p	3		1	19
Total (%)	13 (16%)	6 (7%)	20 (24%)	43 (53%)

As visual loss was often due to cerebral visual impairment, it is not surprising that poor visual outcome and severe neurologic outcome were correlated (Fisher's exact test, P=.0005) (Table XIV). While initial visual reaction was also correlated with final visual outcome, initial visual reaction showed only a weak correlation with final neurologic outcome, possibly due to somewhat different groups of patients for which each characteristic was known. The presence or bilaterality of retinal hemorrhages was not correlated with neurologic outcome.

DISCUSSION

This large series of SBS patients has many characteristics similar to the general series of SBS patients previously reported.[30,46] Most of the patients were very young, there was a majority of boys, and one fourth of the patients had been born prematurely, had chronic medical problems, or were developmentally delayed prior to their injury. In the other study on the patients seen from 1990 to 1995, falls were commonly volunteered as the cause of the injuries, the perpetrators were most often male, and long bone and rib fractures were common.[42] Multiple episodes of trauma were apparent from the ages of the injuries in many patients. Previous and subsequent need for investigation by social service and court agencies was apparent. The percentage of minority patients in this series is larger than in this hospital's patient population. This may reflect where minority patients obtain emergency care or, unfortunately, a lesser suspicion for SBS in medical encounters with white families.[18] That SBS can occur in any ethnic, socioeconomic, gender, age, or education group is still not appreciated universally.[30] The fact that at least one fourth of our patients had a recent previous medical encounter indicates a continued difficulty in recognizing SBS early, as in other series.[30]

Since SBS is often occult, milder cases probably escaped detection clinically.[30] Even for children who die, some do not have enough forensic evidence to make a definitive diagnosis of homicide. The true denominator for SBS studies is unknown.

As in other series, almost one third of our patients died.[47,48] Two ocular findings—lack of visual responsiveness and lack of pupillary reaction—were highly correlated with patient demise. This is not surprising, since they are signs of severe coma, well known to intensive care physicians.[49-51] These findings are prognostic signs that ophthalmologists may not see because they often examine these patients after they have received sedation or seizure medications or the patients have deteriorated neurologically. The pupil size and reactivity could be altered, and the patient would be expected to be unresponsive. These findings have been featured less often in ophthalmology series, which tend to emphasize fundus findings or signs of direct-impact trauma. Mills[25] found a significant relationship between no visual response and death but not for unreactive pupils in his 10 patients.

Death was also correlated with the presence of RH in the present series. The 5 patients who presented late with only large heads may have had RH that resolved before the patients were seen. Half of the patients who had circular folds died, a higher percentage than for the entire series, which was 29%. However, since this is a rare condition, occuring in only 6% of this large series, it is a less useful predictor.[25]

We, like Greenwald and associates,[34] found that abnormal pupillary reaction in eyes of survivors reflected serious vision loss secondary to retinal or optic nerve injuries. Levin[52] reported that up to one third of abused patients with ocular involvement have pupillary abnormalities.

Motility defects observed acutely and chronically reflected the injury to cranial nerves and motor control areas and the sensory strabismus due to retinal or optic nerve injury, as in other series.[53]

In this study, the clinical incidence of retinal hemorrhages was 82%, increasing to 84% when histopathologic observations were included. Previous studies have shown an incidence of 50% to 100%.[14,16,27,33,53-57] In some series, RH was used as an inclusion criterion, increasing the percentage.[24,58] If we excluded patients where RH had not been found by nonophthalmologists and the diagnosis of possible SBS was made from other findings, the incidence was still very high, at 70%. Most patients had bilateral RH, also previously reported.[53] One victim had only one RH in 1 eye clinically, as reported by Greenwald[59] as well.

Retinal hemorrhages were noted clinically most often in the posterior pole of the fundus in this series, similar to the findings of Levin.[52] Little comment had been made clinically on the extent of RH in the 11 patients later examined after death. In the autopsy portion of this study, most eyes had diffuse RH with no predominant location. Other autopsy series have noted a greater predominance of RH near the ora serrata, followed by the posterior pole and the least amount of RH at the equator.[28,33]

The patients presented here rarely had scleral depression. The posterior pole hemorrhages allowed the diagnosis of SBS to be made, and examinations were kept to a minimum in these fragile patients. In only 1 eye was the presence of RH found on autopsy examination and not clinically. The patient's other eye had many RH, so the diagnosis of SBS was not missed. Perhaps scleral depression would have revealed more hemorrhages in the patients where no RH were found.

Asymmetry of retinal hemorrhages was noted commonly in this autopsy series, as in others,[60,61] but less often clinically. This observation is easier to make when both eyes can be seen simultaneously. The full extent of hemorrhages is more easily seen as well. More rapid resolution of RH in the less affected eye of an asymmetric pair may explain why some patients appear to have only unilateral RH when the patients finally come to medical attention.

As in the autopsy series of Rao and associates,[62] RH were noted at all levels of the retina. A predominance in the superficial retinal layers or below the sensory retina,[63] or in the internal layers,[60] was not found. Dome-shaped hemorrhages under the ILM were not common in this series. They were recognized clinically most often in the macular area but were found in any area of the retina on histopathologic examination, as reported elsewhere.[59,60]

Papilledema was infrequent among living patients and common in autopsy patients, similar to the series of Levin[52] and Rao.[62] As in other series, optic nerve sheath hemorrhage was almost universal.[62,64,65] There were 3 cases with this finding in which no RH was found, similar to findings of Riffenburgh.[38] Intrascleral hemorrhage was rare compared to other series.[15,19,63]

The case with peripheral retinal scars similar to those reported in numerous French patients[44,45,66] and several English patients[43] appears to be the first reported autopsy study. Many of the French patients showed signs of facial battering, and some had retinal detachments in the opposite eye, always a sign of direct globe trauma in abused children, according to Greenwald.[59] The filtering angle recessions in the case presented here add evidence that direct-impact injury is the cause of these lesions.

Blindness and poor vision in survivors have been mentioned in many studies,[46,48,53,55-57,67-71] but the frequency of vision loss and the cause often are not given. This study, like many others, is limited by lack of follow-up for many patients but has one of the higher rates of follow-up.[47] The group of visually impaired patients with more than amblyopia represent one of the larger series on their own (Tables XII and XIII). Cerebral visual impairment was the most common cause of the profound visual acuity loss observed.

In the present study, the exclusion of patients who had only impact injuries probably accounts for the low number of direct impact injuries to the globe found, compared to other series.[46,57,67,68,71-73] Occult globe trauma also could have occurred in survivors, as it has been noted on autopsy here and in other reports.[62,67]

The relative frequency of cerebral, ocular, or combined causes for vision loss is often difficult to discern from the literature. Cerebral visual impairment and ocular causes are listed about as often as there is no mention of the cause.[34,47,48,53,56,57,67,69,74-80] Bilateral retinal scarring can occur, both from retinoschisis[34] and from retinal and vitreous hemorrhage, as in Terson's syndrome.[36,74] Both cerebral and ocular reasons have been listed for the vision loss of a few patients.[74,80] Homonymous hemianopsia has been reported previously.[52,57,69,79,81] Visual field defects are not surprising in view of the brain injury. The large contribution of central nervous system problems to vision loss suspected in other series has been confirmed here.[52,57,81,82] Many of our patients had global bilateral hemispheric injury on later CT scans rather than isolated occipital lobe damage.[57]

In this series, retinal disorders were apparent more often in the patients with unilateral vision loss. Other patients with less apparent bilateral retinal injury could have been missed because ERGs were not done.[34,80] The lack of therapeutic benefit to this testing precluded its acceptance. One other survivor with bilateral high myopia has been noted by Sinal and Ball.[56] It is not clear if that patient had good or poor vision with spectacles. High myopia, probably caused by vision deprivation, has been reported in infants who had vitrectomies for persistent vitreous hemorrhage.[83] In the patient reported here (patient 6, Table XII), the original eye findings are not known.

That visual outcome was good in 49% of survivors in the present series and probably good in 19% of those without follow-up because they saw well initially (Table XI) is encouraging news for this grim condition.

While the neurologic outcome of our patients is incompletely known, it is apparent that a substantial number are seriously impaired. Long-term follow-up is needed to know the final degree of impairment, because continued improvement in functional status over several years was noted in an earlier study at this hospital,[41] while neurologic impairment became more obvious in another series.[70]

As shown here and elsewhere, finding retinal hemorrhages is difficult for nonophthalmologists, who are handicapped by limited equipment and presence of constricted pupils and who are burdened by the higher duty of saving the child's life.[49,53,68,84] This series was not planned as a study of the abilities of nonophthalmologist versus ophthalmologists. The nonophthalmologists were not aware that their findings were going to be assessed. However, this series does show actual medical experience. The use of dilating drops by 2 attending pediatricians is commendable. It is encouraging how many patients had ophthalmology consultations, although these were often at the prompting of the Child Advocacy Center, so a suspicion of abuse was already present. There has not been a study in which all infants admitted for irritability, lethargy, or "rule out sepsis" had dilated funduscopic examinations. Hopefully, the yield of such a survey would be low, but for the patients found, it could be life-saving.

Caffey[85] strongly recommended attention to eye findings 25 years ago, and Dykes[86] repeated the recommendation in 1986, long after CT scans became routine. Yet patients suspected of having SBS still receive inadequate eye examinations. The greater ability to detect SDH by CT and magnetic resonance imaging (MRI) scans may have discouraged the practice of basic fundoscopy as the scans have for careful neurologic examinations. Yet the presence of RH is a strong predictor of abnormal CT scans, making it easier to decide which patients should be scanned.[13]

The 15 patients in whom retinal hemorrhages were found only after death were moribund on presentation. All deaths without a previously known fatal condition are investigated by this county's medical examiner. Perhaps the knowledge of this impending investigation, which includes the eyes in all children, also caused a de-emphasis on the fundus examination in this intensive care unit. However, this means that a few SBS cases could be found sometime after death, when crime scene investigations may be much less informative or perpetrators may have fled. The tenacity and conscientiousness of investigation by a medical examiner is highly individual, as experienced in the course of this series.

The discovery of RH in a young child is extremely important diagnostically to emergency department physicians.[87] The systemic evaluation will take an abrupt turn from pursuing sepsis or gastroenteritis to radiologic studies of the brain and bones. The child then has a chance of being protected from further abuse.[32] Concern has been raised from a number of cases in which RH were found, but the initial CT scans were felt to be normal so SBS was in doubt.[88] Subsequent CT scans showed SDH. Levin and associates[89] published a similar case with RH where the initial CT scan was normal but MRI showed hemorrhage and contusion. How often this would occur with current CT scan capabilities and radiologic expertise is not certain. Both cases reinforce the significance of the finding of RH.

However, ophthalmologists, knowing the myriad causes of RH and the nonspecific appearance of RH, did not appear to realize how likely abuse is when RH are found in a child less than 3 years old.[24,33] At this hospital, ophthalmologists, like pediatricians and radiologists before them,[2] appear reluctant to suggest abuse. They are not immune to the common coping methods of denial and avoidance when faced with an unpleasant situation. The most likely causes for RH in an infant are birth, abuse, severe coagulopathy, accidental trauma, and infection, with other causes being much less likely[90] (see Appendix). If the child is more than 3 weeks old and did not have a traumatic birth, the first cause is eliminated. Abuse is so life-threatening to a young child and RH correlates so highly with SDH from various causes that serious consideration of a CT scan should be made for any child with RH. Hemophilia, von Willebrand's disease, and vitamin K deficiency are the coagulopathies in which milder trauma can cause intracranial bleeding. This bleeding can be life-threatening in these children also, so scanning should be done.[91,92] These disorders can be ruled out with hematologic testing; generally only mild coagulopathies occur secondary to intracranial hemorrhage in children with normal coagulation.[93] Accidental trauma very rarely causes RH, and it is usually severe trauma. Short falls less than 4 feet, rough-housing, and falling back against a wall do not cause intracranial hemorrhage.[30] A hard-to-believe history should be a red flag alert for abuse for any physician, including ophthalmologists, who are the first physicians to see abused children about 4% of the time.[73] Finally, meningitis causes retinal hemorrhages rarely; negative cultures point away from this.[53,94,95]

Unfortunately, there are no clinical ocular findings that are pathognomonic for SBS. Pursuit of the exceptional case showing that RH, circular retinal folds, and dome-shaped hemorrhages can occur in other conditions is apparent in the literature.[26,47,95-102] Retinal hemorrhages also cannot be accurately dated.

The posterior orbital hemorrhage seen in autopsies of SBS patients still appears to be unique to SBS.[103] However, in this series, no CT scan correlations could be made for the orbit or optic nerve. Perhaps MRI scanning as soon as patients are stable enough for a prolonged test could reveal orbital and optic nerve sheath hemorrhage.

Fortunately, ophthalmologists can do more for SBS patients than document their retinal hemorrhages for forensic purposes. Short-term follow-up is necessary with large, dome-shaped hemorrhages, as they can break into the vitreous and linger for months in these visually immature patients. Vitrectomy should be considered for these patients, particularly if the ERG response is good.[34,37,80,83] The retinal injuries may limit vision. A few patients have been reported to see well after vitrectomy.[36,37]

Since as many as one third of patients have strabismus,[52] the longer-term management of amblyopia and correction of refractive errors can help maximize vision to the potential left by retinal and brain injuries. With the frequent neurologic, intellectual, and psychological handicaps these patients can have, maximizing their ability to learn visually will help their overall outcome.[41,70] Even for those children with poor vision that cannot be improved, early intervention programs to promote auditory and tactile learning can help them function better.

CONCLUSION

It is extremely rare that a child with a shaking or shaking-impact injury would present initially to the ophthalmologist. Some children who are shaken clearly have had more than 1 injury, which they have survived without medical attention at home. It is possible that one of these children could be seen for an eye examination after a milder injury that has caused retinal hemorrhages but has not caused prolonged loss of consciousness. However, young infants are not routinely examined by an ophthalmologist unless they have a health issue such as a history of significant prematurity of retinopathy of prematurity. Even though premature babies are at a greater risk for abuse, the possible number of abuse patients presenting this way is small. On that rare occasion, the ophthalmologist needs to keep abuse at the top of the list of differential diagnostic possibilities when RH are found.

The ophthalmologist is much more likely to serve as a consultant when abuse has been suspected. Retinal hemorrhages may have already been observed or suspected. The child may show other suspicious signs, such as subdural hematoma or fractures.

However, as shown here, the nonophthalmologist has great difficulty in finding RH, missing one of the most valuable physical findings for SBS. Efforts to make emergency department physicians more comfortable with dilating the pupils, or even with using a small-pupil indirect ophthalmo-

APPENDIX: CAUSES OF RETINAL HEMORRHAGES IN YOUNG CHILDREN

CAUSE	REPORTED FREQUENCY IN INFANTS	CHARACTERISTICS OF HEMORRHAGE	SUPPORTING HISTORY	SUPPORTING LABORATORY	COMMENTS
Birth[90]	3% with cesarean section[104] to 50% with suction extraction[105]	Splinter, flame-shaped, dot and blot. Rarely preretinal or vitreal. May have white centers.[105]	Infant is <3 wk old. Difficult delivery. Vacuum extraction.[105] Much less likely with cesarean section.[104]		Rapidly resolve.[106] Rarely cause permanent loss of vision, even when in the macula.[107]
Shaken baby syndrome	50%-100% of cases[14,16,24,27,33,53-58]	All types. Preretinal and vitreal hemorrhages common. Retinal folds and retinoschisis ocur rarely.	History is absent or not compatible with severity of injury	CT scan of head showing SDH and cerebral edema radiographs showing rib and other fractures	Obvious signs of direct ocular or orbital trauma are rare. Often RH are bilateral, large and numerous but not necessarily.
Accidental trauma	Case reports, 0%-2% in series[13,24,27,33,61,108-110]	Usually small in number and size	Severe injury: auto accident,[109] falling down stairs in walker[111]		Not commonly severe[64,111]
Cardiopulmonary resuscitation (CPR)	Case reports,[22,99] 2%-10%	Usually small in number and size	History of CPR. However, a	Rarely have posterior rib	A rare cause, extremely rare

APPENDIX (CONTINUED): CAUSES OF RETINAL HEMORRHAGES IN YOUNG CHILDREN

CAUSE	REPORTED FREQUENCY IN INFANTS	CHARACTERISTICS OF HEMORRHAGE	SUPPORTING HISTORY	SUPPORTING LABORATORY	COMMENTS
	in small series.[87,98,110,12,113] 0 in 49 patients without head injury.[114]		history of CPR, sometimes with shaking, is often given to cover up abuse.	fractures as seen with shaking	in sudden infant death syndrome[64,95,97]
HEMATOLOGIC DISORDERS					
Leukemia	Exact frequency in children <3 yr old is unknown. Probably common.[115]	Splinter and dot hemorrhages, some with white centers.[116] Preretinal and vitreous hemorrhages, exudates.	No trauma, fatigue	Blood cell analysis	
Hemophilia, von Willebrand's disease.	Unknown; could occur as part of intracranial bleeding[91,117]	All layers of retina as well as vitreous	A minor fall at play can cause intracranial bleeding.[118]	Coagulation studies	Definitive hematologic diagnosis can take several days. Mild coagulation disorders can

APPENDIX (CONTINUED): CAUSES OF RETINAL HEMORRHAGES IN YOUNG CHILDREN

CAUSE	REPORTED FREQUENCY IN INFANTS	CHARACTER-ISTICS OF HEMORRHAGE	SUPPORTING HISTORY	SUPPORTING LABORATORY	COMMENTS
					be caused by abusive head trauma alone.[93]
Vitamin K deficiency	Rare in United States[119,120]	Can be as severe as in SBS	Home birth, exclusively breast-fed. Bleeding from many sites, bruising	Coagulation studies can look very much like SBS	Intracranial hemorrhage
Thrombo-cytopenia and anemia from various causes	Rare in children[121,122]	Flame-shaped, occasionally preretinal or vitreal.	No trauma	Blood cell analysis	
Protein C[123]	Rare	Vitreous hemorrhage	Bleeding from many sites, bruising	Coagulation studies	Similar to Vitamin K deficiency
INFECTION					
Meningitis [53, 94, 124, 125]	Infrequently reported	Any type	Systemic illness	Cerebral spinal fluid	May be due to disseminated

APPENDIX (CONTINUED): CAUSES OF RETINAL HEMORRHAGES IN YOUNG CHILDREN

CAUSE	REPORTED FREQUENCY IN INFANTS	CHARACTER-ISTICS OF HEMORRHAGE	SUPPORTING HISTORY	SUPPORTING LABORATORY	COMMENTS
				testing	intravascular coagulation
Malaria[126]	Common in endemic areas	Multiple retinal hemorrhages. Papilledema, extra macular edema.	Systemic illness	Peripheral blood smear	
Acquired immune deficiency syndrome [127]	Rare in children under 12 yr old	As part of cytomegalovirus infection	Systemic illness	Human immuno-deficiency virus testing	Rare
OTHER INTRACRANIAL HEMORRHAGE					
Arteriovenous malformation, aneurysm,[64,100] Terson syndrome	Case reports in children[64,100,101]	Can be very extensive with dome-shaped retinal hemorrhages. Papilledema secondary to increased intra-cranial pressure.	No trauma. Acute neurologic deterioration.	CT scan	Can appear identical to SBS. Lack of history of trauma can appear suspicious.
Extracorporeal	Extremely	Small, in posterior	History of ECMO		Screening ECMO

APPENDIX (CONTINUED): CAUSES OF RETINAL HEMORRHAGES IN YOUNG CHILDREN

CAUSE	REPORTED FREQUENCY IN INFANTS	CHARACTERISTICS OF HEMORRHAGE	SUPPORTING HISTORY	SUPPORTING LABORATORY	COMMENTS
membrane oxygenation (ECMO)	rare[128-130]	pole			patients for retinal hemorrhages has an extremely low yield.[130]
Purtscher's retinopathy	Rarely reported in young children[131]	Superficial exudates and hemorrhages	Crushing head or chest injury	Bruising, fractures of skull or chest	Could occur in other physical abuse than SBS[78]
METABOLIC DISORDERS					
Glutaric acidemia type 1	Rare in medical literature <100 patients).	Identical to SBS[132]	No trauma. Increased head size due to subdural hematomas.[133]	Glutaric acid in urine. Very low glutaric acid dehydrogenase level.	Has been mistaken for SBS, causing great anguish to parents and outrage in the lay press.
Galactosemia[134]	Rare	Vitreous hemorrhage	Failure to thrive	Galactose in urine	Coagulopathy probably leads to hemorrhage. Reduced vision from retinal scarring.
Isolated Ocular Disease	Rare	Coat's disease, ROP, retinal dysplasia	Prematurity, family history		Rare

CT, computed tomography; RH, retinal hemorrhage; SDH, subdural hemorrhage; ROP, retinopathy of prematurity.

scope or a wide-angle contact video fundus camera, could help find these injured babies earlier, before they are severely injured or killed.

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